FIRST RESULTS from the NA60 EXPERIMENT at CERN

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Abstract

Since 1986, several heavy ion experiments have studied some signatures of the formation of the quark-gluon plasma and a few exciting results have been found. However, some important questions are still unanswered and require new measurements. The NA60 experiment, with a new detector concept that vastly improves dimuon detection in proton-nucleus and heavy-ion collisions, studies several of those open questions, including the production of open charm. This paper presents the experiment and some first results from data collected in 2002.

In the study of the possible formation of a deconfined state of strongly interacting matter, where chiral symmetry is restored, by colliding heavy nuclei at high energies, a few very interesting observations have been made. However, certain aspects in the interpretation of these measurements remain unclear and require a better look. The NA60 experiment addresses some of these issues, namely those that can be studied through dilepton production.

The dimuon continuum in the mass window between the ϕ and the J/ψ resonances is very well described in proton-nucleus collisions by simply adding the Drell-Yan dimuons to the expected yield of muon pairs from simultaneous semi-muonic decays of D meson pairs. In S-U and Pb-Pb collisions, however, the data exhibits an important excess with respect to these expected sources [1]. This excess may be due to a rather strong enhancement of charm production (up to a factor 3 in central Pb-Pb collisions) or to thermal dimuons produced in the quark gluon plasma phase. NA60 will distinguish these two possibilities and directly measure the open charm yield, an important measurement in itself, being the heaviest flavour

that can be produced today in heavy-ion collisions and given the significant enhancements observed in the (multi-)strangeness sector.

So far, charm has only been studied through J/ψ and ψ' production, $c\bar{c}$ bound states, namely in the NA38 and NA50 SPS experiments. The well-known J/ψ "anomalous suppression" [2] is generally considered to be one of the most interesting observations done so far in the context of the search for the formation of the quark-gluon plasma phase. However, its detailed interpretation poses some difficulties. For instance, it is likely that what is being suppressed is the χ_c meson, responsible for around 30–40 % of the J/ψ mesons measured in elementary pp collisions. It is also very strange that this (χ_c) suppression happens at rather high energy densities, higher than 2 GeV/fm^3, while the value expected from lattice QCD calculations is $\epsilon_c \sim 0.7$ GeV/fm^3. Maybe the energy density is not the variable driving charmonium suppression. To clarify these questions, NA60 will complement the S-U (NA38) and the Pb-Pb (NA50) data with a detailed study of In-In collisions.

Also the CERES experiment observed a very interesting excess of dileptons in the mass window around 500 MeV, equally seen in S-Au and in Pb-Au collisions [3]. It is tempting to associate these observations with the predicted restoration of chiral symmetry in the hot and dense medium created in these collisions. NA60 will provide a new measurement, using dimuons instead of dielectrons, with completely independent systematic uncertainties and good statistics, mass resolution and signal to background ratio. Surely, the new measurements will be very helpful in clarifying the interpretation of these results.

The NA60 experiment complements the muon spectrometer and zero-degree calorimeter (ZDC) previously used in NA50 with a completely new detector concept in what concerns the target region. The basic idea is to place an "eye" in the vertex region, composed of state-of-the-art silicon detectors that track the beam and the particles produced in the target, within the angular acceptance of the muon spectrometer [4].

The beam tracker is composed of two silicon microstrip stations, placed 20 cm apart, just upstream of the target. The sensors have 24 strips of 50 μm pitch, allowing to infere the *transverse* coordinates of the interaction point, at the target, with a resolution of 20 μm. Being operated at 130 K, in vacuum, we have seen (in year 2000) that these sensors continue to be sensitive to the beam ions even after more than 30 days of continuous running, with beam intensities of 7×10^7 Pb ions per burst. At room temperature, we would not expect the sensors to survive the first day. The very fast signals (rise time less than 500 ps) together with a devoted (and fast) multi-hit time recorder system, ensure a time accuracy of 1.7 ns and a double-peak resolution better than 10 ns, useful to reject beam pile-up.

After the target, and inside a 2.5 T dipole field, sits the silicon tracking telescope, that tracks the charged particles produced within the angular acceptance of the muon spectrometer. For the ion runs, the telescope is made of silicon pixel detectors, to cope with the very high particle multiplicities produced. In the proton runs we can also use microstrip planes, to extend the tracking distance up to 40 cm from the target, with much less material budget than with pixel assemblies, and using a faster clock (40 MHz), relevant to fight interaction pile-up at the very high proton beam intensities (more than 10^9 protons per 5 s burst).

The NA60 silicon pixel telescope will consist of eight 4-chip pixel planes (illustrated in Fig. 1) followed by 4 large stations, each made of two 8-chip planes, to cover the solid angle defined by the muon spectrometer. The read-out pixel chip is a matrix of 256×32 pixels, each cell being 50×425 μm^2. These chips were designed for the ALICE and LHC-B experiments [5], work at 10 MHz and are radiation hard up to around 30 Mrad. They are bump-bonded to 300 μm thick silicon sensors and assembled in ceramic hybrids. The DAQ system reads the almost 1 million pixel channels through a PCI-based read-out electronics system.

The silicon vertex telescope tracks the charged particles and selects those that provide the best match to the muons identified and measured in the muon spectrometer. The matching allows us to access the angles and momenta of the muons before they suffer the multiple scattering and energy loss induced by the absorbers, thereby significantly improving the dimuon mass resolution. Since the matching probability is lower for muons from K and π decays, the signal to background ratio is also improved. Finally, measuring the offset in the transverse plane between the muon's trajectory and the interaction point allows us to distinguish an event sample dominated by muons resulting from decays of charmed mesons

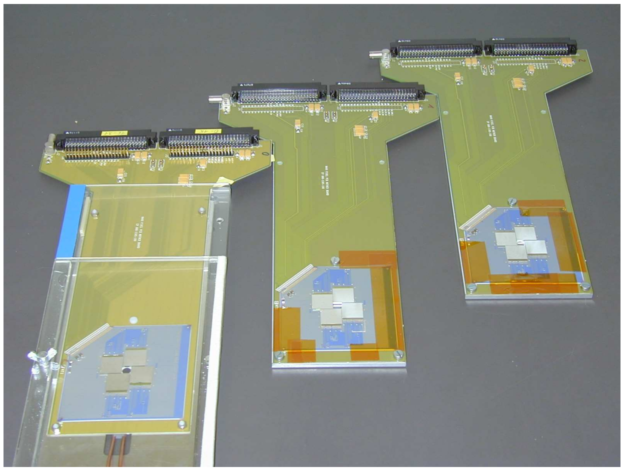

Figure 1: 4-chip planes used in October 2002.

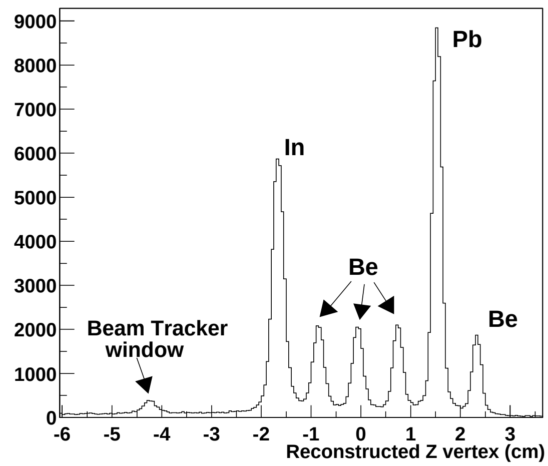

Figure 2: Z-vertex distribution for the p-A run.

from an event sample composed of prompt dimuons.

During around two weeks in June 2002, NA60 collected proton-nucleus data, using a dimuon trigger and a 400 GeV proton beam incident on Be, In and Pb targets. The targets (6 in total) were placed every 8 mm and were 2 mm thick, while the interaction point was reconstructed from the tracking of the charged particles in the silicon telescope with a resolution of $\sim 900\ \mu$m, in the beam direction (see Fig. 2). The dimuon mass, after matching, is measured with a resolution around 25 MeV at the ω mass and around 30 MeV at the ϕ mass (see Fig. 3), a major improvement with respect to NA50. Furthermore, the acceptance for low mass dimuons extends now down to very low p_{T} (see Fig. 4), mostly thanks to the presence of the dipole magnet in the target region, which bends into the acceptance of the muon spectrometer tracks that would otherwise be lost in the beam dump. This should allow NA60 to perform measurements complementary to CERES and, also, should provide a p_{T} distribution of the ϕ that overlaps with the measurements of NA49, contrary to NA50 data.

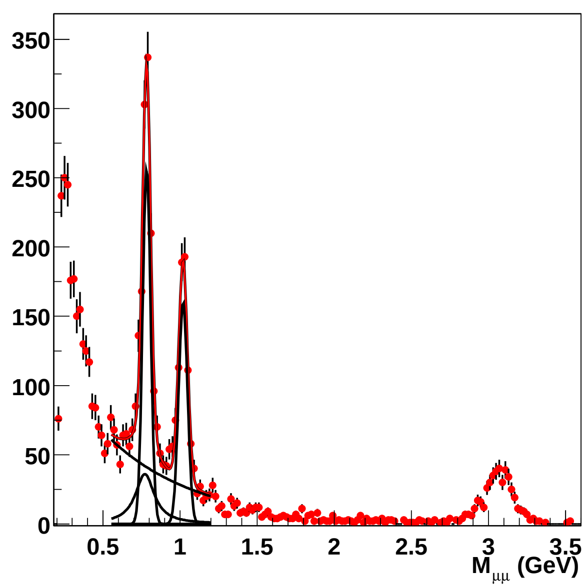

Figure 3: Dimuon mass distribution for p-Pb collisions

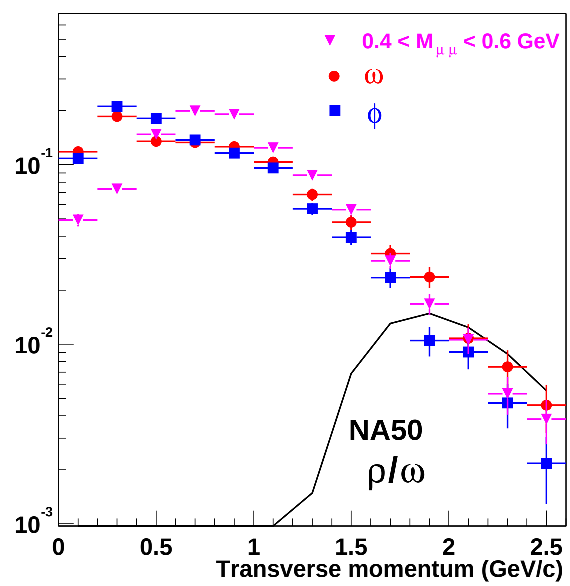

Figure 4: p_{T} distributions measured for different mass regions.

In October 2002, NA60 had a test run with a Lead beam of 30 and 20 GeV per nucleon (5 days each), incident on three Lead targets of different thicknesses: 1.5, 1.0 and 0.5 mm,

along the beam. Three pixel planes were successfully operated and were able to track the several tens of charged particles produced in their angular acceptance. In spite of the small number of tracking planes, the vertex of the Pb-Pb collision could be reconstructed with a resolution better than 200 μm along the beam direction (see Fig. 5), and of around 20 μm for the X transverse coordinate (all the three planes had the 50 μm side of the cells along the X coordinate), as expected from the physics performance simulations.

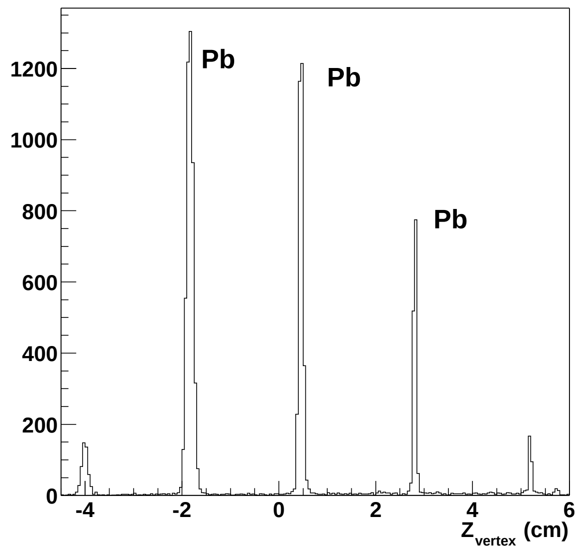

Figure 5: Z-vertex distribution measured in Pb-Pb collisions, during the 30 GeV per nucleon run.

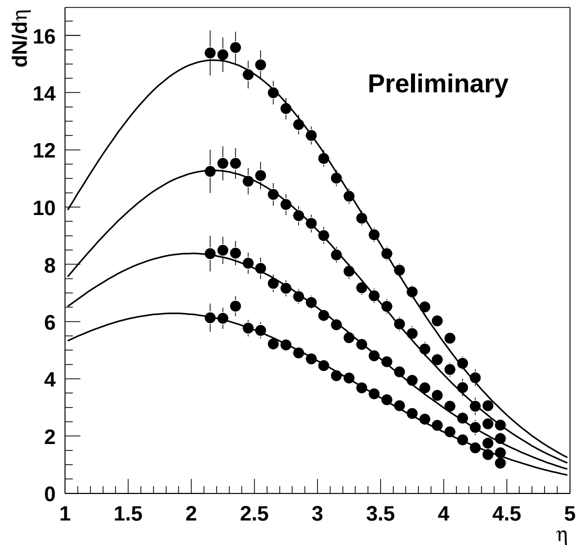

Figure 6: Rapidity densities of charged particles measured for different centrality ranges.

As a by product of the Pb test run, we measured the rapidity densities of the charged particles produced in the 30 GeV per nucleon Pb-Pb collisions, for several centrality classes estimated through the ZDC, as can be seen in Fig. 6. For this measurement, the three pixel planes were placed as close as possible to the targets, so that the angular coverage would include mid-rapidity (2.08 at an incident energy of only 30 GeV/nucleon), and the multiplicity was estimated through a cluster counting procedure [6]. Acceptances and efficiencies were considered for each target and each pixel plane. The spurious contributions from secondary interactions and from δ-rays produced by the incident ions were estimated through Monte Carlo simulation, using UrQMD and GEANT.

In conclusion, NA60 has taken first data in year 2002, with proton and Pb ion beams, with a new silicon vertex telescope in the target region. With the proton runs we have collected dimuon data showing good mass resolution and improved acceptance for low mass and p_{T} dimuons. In the ion run we measured the interaction point with excelent accuracy. These results confirm the feasibility of the experiment and give good perspectives for the next runs with proton and Indium beams.

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